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OPTICAL INTERACTIONS IN SOLIDS RELATING  
TO SOLID STATE DETECTORS AND CORROSION  
CONTROL

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The optical properties of cadmium arsenide, cadmium phosphide alloys are reported. The infrared characteristics of synchrotron radiation as a possible source for infrared spectroscopy and detector calibration have been studied. The relation of the extreme ultraviolet reflectance to the optical constants generated by a Kramers-Kronig analysis with applications to the cadmium-zinc-arsenide alloy are reported. The results of Auger electron spectroscopy and optical spectroscopy of magnesium-magnesium oxide surfaces are given with possible applications to		

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corrosion studies and optical characterization of surfaces.

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# Final Scientific Report

# Optical Interactions in Solids Relating to Solid State Detectors and Corrosion Control

James R. Stevenson

November 12, 1974

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## OBJECTIVES

The purpose of the research has been a study of optical interactions in solids and related physical properties of solid surfaces. Particular emphasis in the study was given to some complex tertiary semiconductor alloy systems. Although complex in nature, evidence exists for believing the semiconductor alloys will have important device applications in the future e.g. the variation in band gap with alloy composition. The research concentrated on the determination and analysis of data related to surface characterization such as that obtained from optical reflectivity and auger spectroscopy. The techniques and data are directly related to factors contributing to an understanding of surface stability and corrosion control in semiconductor devices. Synchrotron radiation from the electron storage ring at the Physical Sciences Laboratory of the University of Wisconsin was utilized to provide a continuum source in a compatible high vacuum environment. In addition the infrared characteristics of existing and proposed synchrotron radiation sources were investigated as possible infrared sources for application to infrared solid state spectroscopy.

## ACHIEVEMENTS

1. An exhaustive study of the optical properties of the  $\text{Cd}_3\text{As}_2\text{-Cd}_3\text{P}_2$  alloy system has been completed in the form of a PhD thesis by Dr. Maury Zivitz. The work has recently been published in Physical Review. The thesis is available as a report of the School of Physics of Georgia Institute of Technology. As this effort is part of the available scientific literature no further comments will be included on this phase of the work.
2. The infrared characteristics of synchrotron radiation were investigated as a possible radiation source for infrared spectroscopy and detector calibra-

tion. The results of this research has resulted in considerable interest within the scientific community. Details of the research were published in Applied Optics and a supplement to the paper is available as a report of the School of Physics, "Computer Calculations and Numerical Tabulations of Some MacDonald Functions". Tabulations of these functions are not available in the current literature.

3. An experimental system including a sample chamber for investigating a surface in ultra high vacuum using optical reflectivity and electron Auger spectroscopy has been developed. The system can be used without a window when the light is from an ultra high vacuum source such as an electron storage ring or with a window when the radiation source is at a higher pressure than desirable for Auger spectroscopy. The details of this system are included in the PhD thesis of Dr. Harry Ellis.
4. A study was completed on the relation of the extreme ultraviolet reflectance to the optical constants generated by a Kramers-Kronig analysis with application to samples of the alloy  $\text{Cd}_{1-x}\text{Zn}_x\text{As}_2$ . This research shows the need for measurements of the optical reflectance in the vacuum ultraviolet even though the interesting structure may be in the near infrared and visible. Dr. Ellis has used a classical model to investigate the effect of high energy extrapolations of reflectivity data. The convergence sum rules and the effects on peak height in the structure of optical constants have been investigated. A complete description of the results is available as the thesis of Dr. Harry Ellis. A talk on the results will be presented to the American Physical Society and a paper will be prepared for publication.
5. Our interest in surface electronic states, passive surface layers, and corrosion led to a preliminary investigation of studying the growth of surface layers via optical reflectivity and electron Auger spectroscopy.

Dr. John Carden, a physical chemist, and two graduate students Mr. Bill Wall and Mr. James Larsen were particularly helpful in the initiation of the research. Using magnesium metal and the formation of the oxide on the surface as the system of interest, we have demonstrated that ultraviolet spectroscopy of the surface will result in an ability to follow the destruction of a passive layer and the growth of a deeper oxide characteristic of corrosion. The possibility of extending these controlled studies into the infrared may result in a systematic selection of wavelengths for non-destructive characterization of oxide depth on the surface. The dramatic change of the optical constants in different wavelength regions as the surface oxide increases in depth may have significant applications not only to corrosion but also in the area of communications. The results of the preliminary investigations have been reported in a talk at the IV International Conference on Vacuum-Ultraviolet Radiation Physics in July, 1974 and will appear in the Proceedings of the Conference.

#### PROFESSIONAL PERSONNEL

The following individuals have participated in the research described above.

1. Dr. James R. Stevenson - Principal Investigator
2. Dr. Roger Bartlett - Postdoctoral Research Associate
3. Mr. Maury Zivitz - Graduate Research Assistant
4. Mr. Harry Ellis - Graduate Research Assistant
5. Mr. Abdol Gholamnezhad - Graduate Research Assistant
6. Mr. Stephen Zehner - Graduate Research Assistant
7. Dr. Douglas Wrege - Computer Consultant
8. Dr. L. N. Tharp - Auger Spectroscopy Consultant
9. Mr. James House - Electronics Technician
10. Dr. John Carden - Auger Spectroscopy Consultant and Research Scientist
11. Mr. Bill Wall - Graduate Research Assistant
12. Mr. James Larsen - Graduate Research Assistant
13. Mr. Samuel Formby - Graduate Research Assistant
14. Mr. Frank Ferrandino - Graduate Research Assistant



# PAPERS PRESENTED

1. "Visible and Vacuum Ultraviolet Reflectance Study of the Semiconductor Alloy System  $\text{Cd}_{3-x}\text{Zn}_x\text{As}_2$ ," Bull. Am. Phys. Soc. 15, 1343 (1970).
2. "Optical Reflectivity Studies in the Vacuum Ultraviolet." Synchrotron Radiation Users Meeting, Physical Sciences Laboratory, University of Wisconsin, Stoughton, Wisconsin, November 19, 1970.
3. "Infrared Reflectance Study of the Semiconductor Alloy System  $\text{Cd}_{3-x}\text{Zn}_x\text{As}_2$ ," Bull. Am. Phys. Soc. 15, 1343 (1970).
4. "Auger Spectroscopy and Optical Reflectivity of the  $\text{Cd}_3\text{Zn}_{3-x}\text{As}_2$  System," Synchrotron Radiation Users Meeting, Physical Sciences Laboratory, University of Wisconsin, Stoughton, Wisconsin, November 29, 1971.
5. "Reflectivity of  $\text{Cd}_x\text{Zn}_{3-x}\text{As}_2$  Semiconductor Alloy Systems," Conference Digest - 3rd. International Conference on Vacuum Ultraviolet Physics, Tokyo, Japan (1971).
6. "Ultrahigh Vacuum Reflectometer", Bull. Am. Phys. Soc. 17, 193 (1972).
7. "Optical Properties of  $\text{Cd}_x\text{Zn}_{3-x}\text{As}_2$ ," Seminar - Group F41 - DESY, Hamburg, W. Germany, August 10, 1972.
8. "A Preliminary Study of the Utility of Synchrotron Radiation for Studies in the Infrared", Physical Sciences Laboratory, University of Wisconsin, Stoughton, Wisconsin, November 27, 1972.
9. "Synchrotron Radiation as a Spectroscopy Source in the Infrared," Bull. Am. Phys. Soc. 18, 464 (1973).
10. "The Optical Properties of  $\text{Cd}_3\text{As}_2$ - $\text{Cd}_3\text{P}_2$  Alloy Systems," Sixth Annual Synchrotron Radiation Users Group Conference-Physical Sciences Laboratory -University of Wisconsin, October 22, 1973.
11. "Use of Synchrotron Radiation for Optical Excitation of Solids," Seminar-Georgia State University, November 26, 1973.

12. "The Optical Properties and Auger Characteristics of Magnesium Single Crystals and Magnesium Oxide and Magnesium Nitride Surface Films", IV International Conference on Vacuum-Ultraviolet Radiation Physics, Hamburg, W. Germany July 22-26, 1974.
13. "The Optical and Auger Properties of Magnesium", Seventh Annual Synchrotron Radiation Users Group Conference-Physical Sciences Laboratory-University of Wisconsin, October 22, 1974.

#### PAPERS TO BE PRESENTED

1. "The Visible and Near Ultraviolet Optical Properties and Auger Characteristics of Magnesium Single Crystals and Magnesium Oxide Surface Films". Bull. Am. Phys. Soc. 19, 1081 (1974.)
2. "Sensitivity of Sum Rules to Extrapolations in Kramers-Kronig Analysis of Reflectivity Data with Application to  $\text{Cd}_3\text{As}_2$ ", Bull. Am. Phys. Soc. 19, 1118 (1974).

#### PAPERS PUBLISHED

1. James R. Stevenson, Maury Zivitz, Harry Ellis and Roger J. Bartlett, "Reflectivity of  $\text{Cd}_x\text{Zn}_{3-x}\text{As}_2$  Semiconductor Alloy Systems," Conference Digest-3rd International Conference on Vacuum Ultraviolet Physics, Tokyo, Japan (1971).
2. James R. Stevenson, Harry Ellis and Roger Bartlett, "Synchrotron Radiation as an Infrared Source, Applied Optics 12, 2884 (1973).
3. Harry Ellis and James R. Stevenson, "Computer Calculations and Numerical Tabulations of Some MacDonald Functions as a Supplement to "Synchrotron Radiation as an Infrared Source", A Report of the School of Physics Georgia Institute of Technology (1973).

4. Maury Zivitz and James R. Stevenson, "Optical Properties of the  $\text{Cd}_3\text{As}_2\text{-Cd}_3\text{P}_2$  Semiconductor Alloy System", Phys. Rev. B 10, 2457 (1974).

#### PAPERS TO BE SUBMITTED OR PUBLISHED

1. John Carden, Frank Ferrandino, James Larsen, William Wall and James R. Stevenson, "The Optical Properties and Auger Characteristics of Magnesium Single Crystals and Magnesium Oxide and Magnesium Nitride Surface Films", Proceedings - 4th International Conference on Vacuum Ultraviolet Radiation Physics-Pergamon Press 1974.
2. Harry Ellis and James R. Stevenson, "Sensitivity of Sum Rules to Extrapolations in Kramers-Kronig Analysis of Reflectivity Data", manuscript in preparation.

#### PH.D. THESES

1. M. Zivitz, "The Optical Properties of the  $\text{Cd}_3\text{As}_2\text{P}_{2-x}$  Alloy System", (1973.)
2. H. Ellis, "Relation of the Extreme Vacuum Ultraviolet Reflectance to the Optical Constants Generated by a Kramers-Kronig Analysis with Application to Samples of the Alloy  $\text{Cd}_x\text{Zn}_{3-x}\text{As}_2$ ".

#### RESEARCH GROUP INTERACTIONS

1. Physical Sciences Laboratory, University of Wisconsin, Madison, Wisconsin.
2. Solid State Division, U.S. Naval Research Laboratory, Washington, D.C.
3. F-41 Group, DESY, Hamburg, W. Germany.
4. T. C. Collins, Wright Patterson Air Force Base, Dayton, Ohio.
5. F. C. Brown Physics Department, University of Illinois.
6. G. J. Lapeyre, Physics Department, Montana State University.

7. D. W. Lynch, Physics Department, Iowa State University.
8. E. T. Arakawa, Health Physics Division, Oak Ridge National Laboratory.
9. T. F. Connally, Research Material Information Center, Oak Ridge National Laboratory.